# Reflection of Sound

# Sound Waves in the Free Field

- Sound in a free field travels in straight lines unreflected, unabsorbed, undiffracted, unrefracted, undiffused, and not subjected to resonance effects.
- Intensity of sound (power per unit area) is a difficult parameter to measure. Sound pressure is easily measured. As intensity is proportional to the square of sound pressure.
- The point source of Fig. 4-1 radiates sound at a fixed power. This sound is of uniform intensity (power per unit area) in all directions.

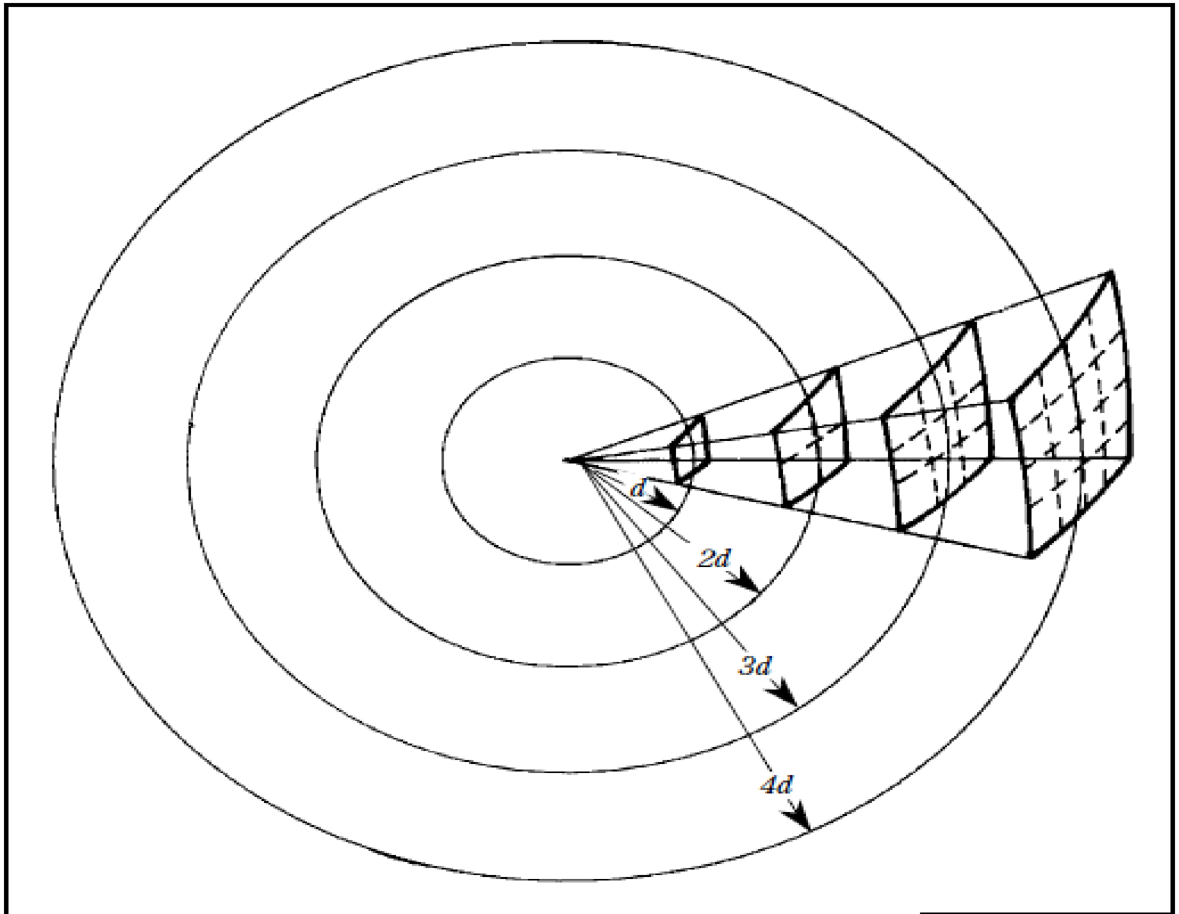


FIGURE 4-1

In the solid angle shown, the same sound energy is distributed over spherical surfaces of increasing area as *d* is increased. The intensity of sound is inversely proportional to the square of the distance from the point source.

When the sound-pressure level $L_1$ at distance $d_1$ from a point source is known, the sound-pressure level $L_2$ at another distance $d_2$ can be calculated from:

$$L_2 = L_1 - 20 \log \frac{d_2}{d_1}, \text{ decibels} \qquad (4\text{-}1)$$

In other words, the difference in sound-pressure level between two points that are $d_1$ and $d_2$ distance from the source is:

$$L_2 - L_1 = 20 \log \frac{d_2}{d_1}, \text{ decibels} \qquad (4\text{-}2)$$

# Reflection of Sound

- If a sound is activated in a room, sound travels radially in all directions. As the sound waves encounter obstacles or surfaces, such as walls, their direction of travel is changed, i.e., they are reflected.
- The diagram shows the reflection of waves from a sound source from a rigid, plane wall surface.

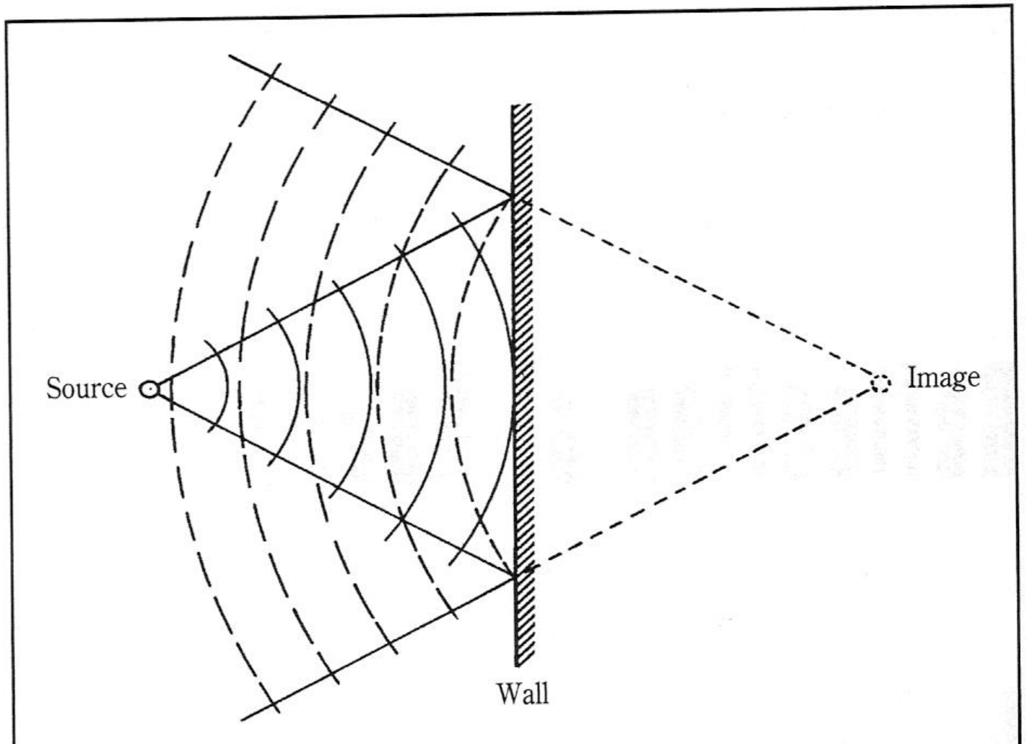


**FIGURE 10-1**

Reflection of sound from a point source from a flat surface (incident sound, solid lines; reflected sound, broken lines). The reflected sound appears to be from a virtual image source.

# Reflections from Flat Surfaces

- Like a mirror, the reflected wavefronts act as though they originated from a sound image.
- The image source is located the same distance behind the wall as the real source is in front of the wall.
- Below 300 – 400 Hz, sound is best considered as waves. Sound above 300 – 400 Hz is best considered as traveling in rays.
- The mid/high audible frequencies have been called the specular frequencies because sound in this range acts like light rays on a mirror.

# Angle of Reflection

- Sound follows the same rule as light: the angle of incidence is equal to the angle of reflection.
- The pressure at the face of a perfectly reflecting surface is twice that of a perfectly absorbing surface.

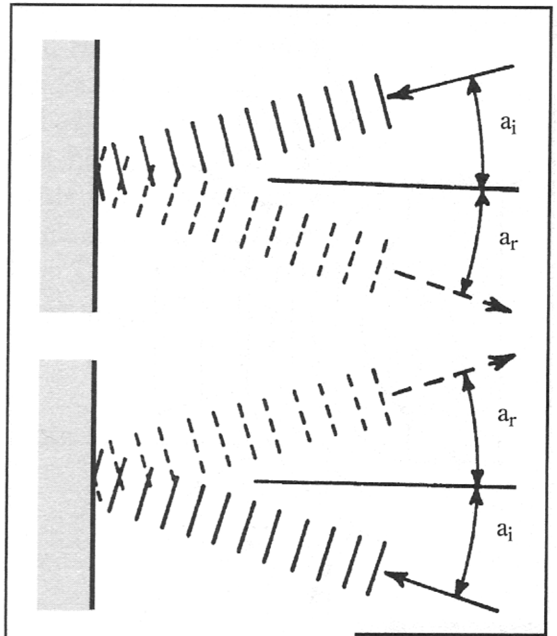


**FIGURE 10-2**

The angle of incidence, $a_i$, is equal to the angle of reflection, $a_r$.

# Reflections from Convex Surfaces

- Reflection of plane wavefronts of sound from a solid convex surface tends to scatter the sound energy in many directions.
- This amounts to a *diffusion* of the impinging sound.

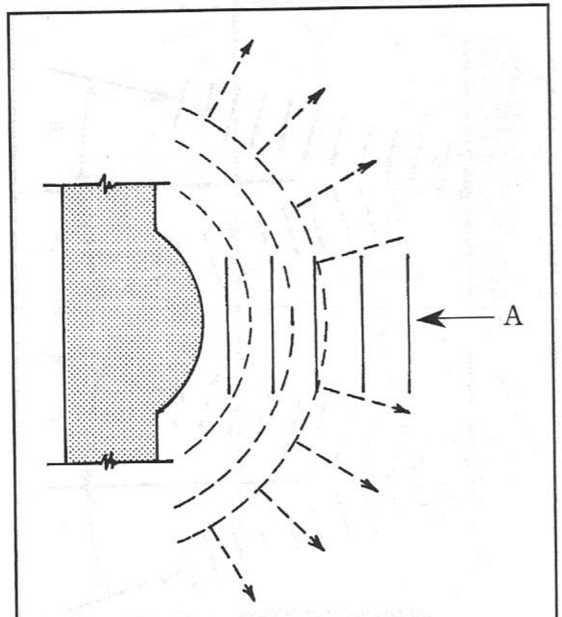


FIGURE 10-3

Plane sound waves impinging on a convex irregularity tend to be dispersed through a wide angle if the size of the irregularity is large compared to the wavelength of the sound.

# Reflections from Concave Surfaces

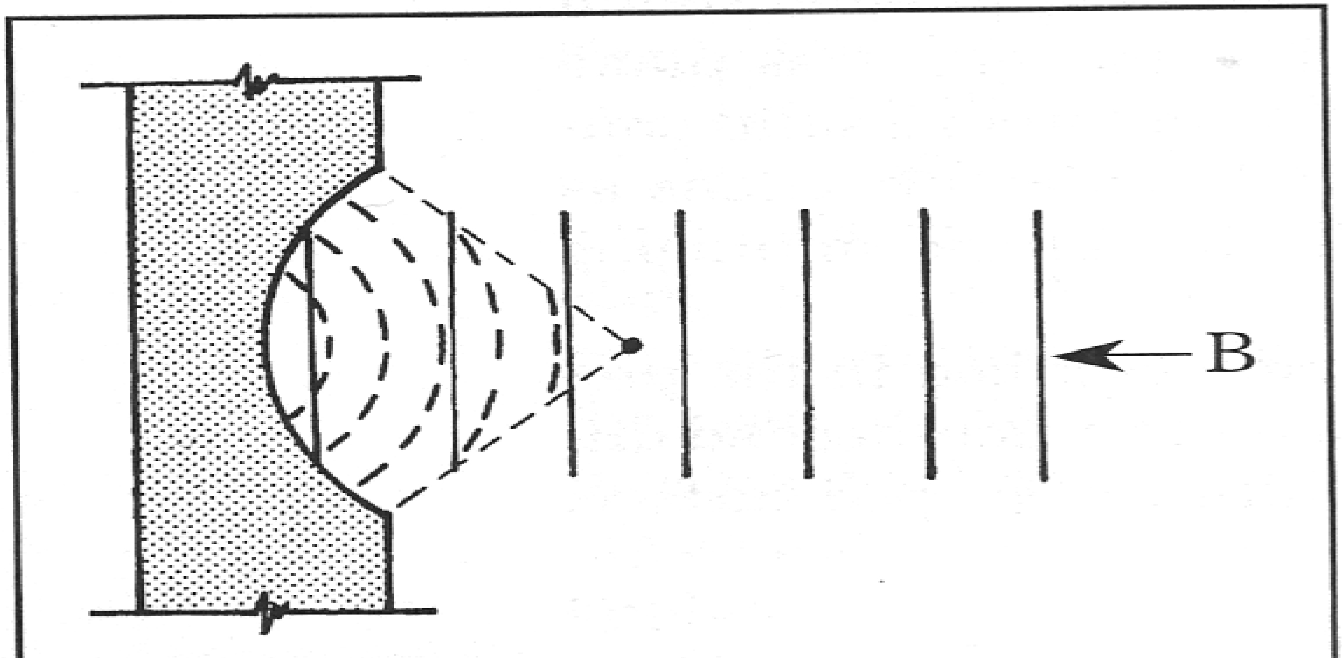


FIGURE 10-4

Plane sound waves impinging on a concave irregularity tend to be focussed if the size of the irregularity is large compared to the wavelength of the sound.

- Plane wavefronts of sound striking a concave surface tend to be focused to a point.
- The precision with which sound is focused is determined by the shape of the concave surface.
- They are often used to make a microphone highly directional by placing it at the focal point. Such microphones are frequently used to pick up field sounds at sporting events or in recording songbirds or other animal sounds in nature.
- Concave surfaces in churches or auditoriums can be the source of serious problems as they produce concentrations of sound in direct opposition to the goal of uniform distribution of sound.

# Reflections from Parabolic Surfaces

- A *parabola* has the characteristic of focusing sound precisely to a point.
- This concept is used in microphone design to create highly directional microphones known as *parabolic mics*.
- A very "deep" parabolic surface, such as that of Fig. 10-5, exhibits far better directional properties than a shallow one.
- The directional properties depend on the size of the opening in terms of wavelengths.

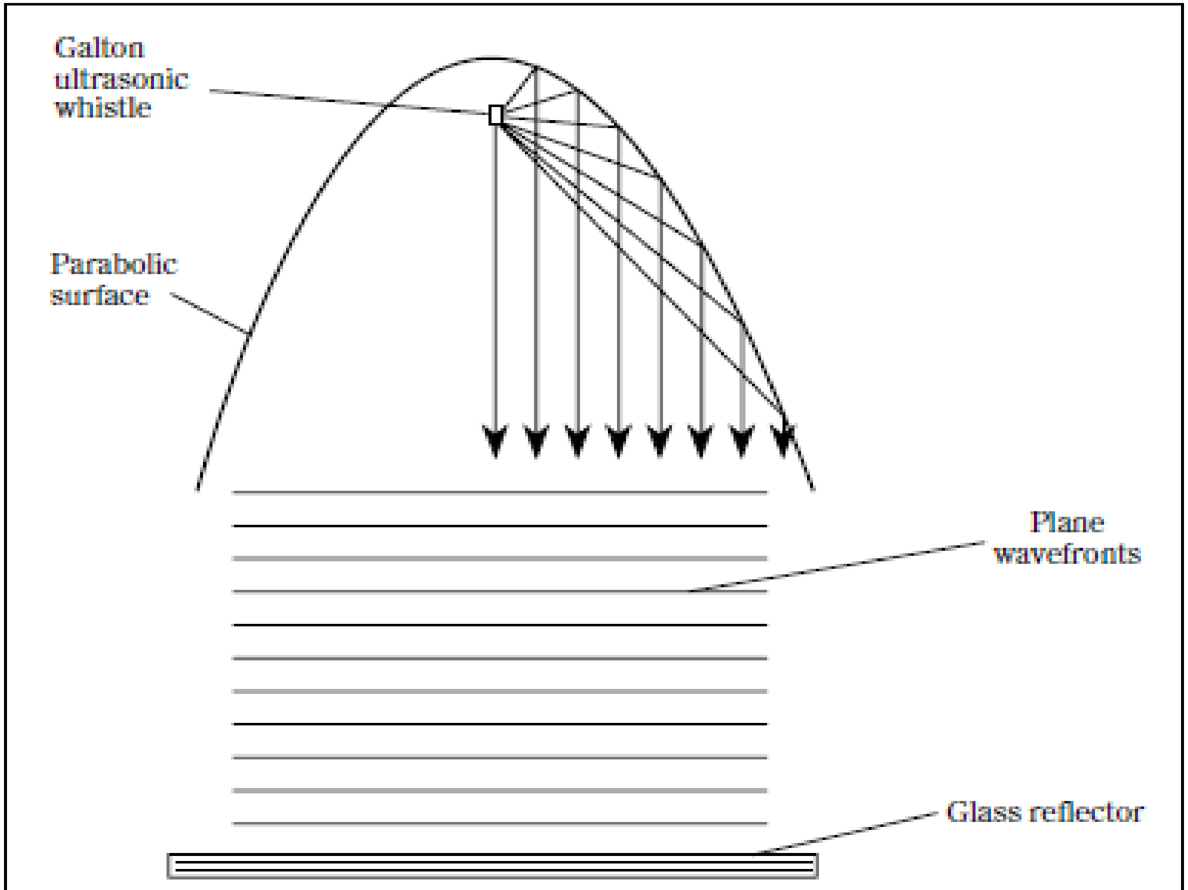


**FIGURE 10-5**

A parabolic surface can focus sound precisely at a focal point or, the converse, a sound source placed at the focal point can produce plane, parallel wavefronts. In this case, the source is an ultrasonic Galton Whistle blown by compressed air with the results shown in Figs. 10-6 and 10-7.

- The parabola used as a directional sound source with a small ultrasonic Galton Whistle pointed inward at the focal point. Plane waves striking such a reflector would be brought to a focus at the focal point. Conversely, sound emitted at the focal point of the parabolic reflector generates plane wave.
- Generally the ceilings of cinema halls and auditoriums are curved so that sound after multiple reflection reaches all parts of the hall.

# Echo

- If we shout or clap near a reflecting surface like tall building or a mountain, we hear the same sound again. This sound which we hear is called echo. It is caused due to the reflection of sound.
- To hear an echo clearly, the time interval between the original sound and the echo must be at least 0.1 s.
- Since the speed of sound in air is 344 m/s, the distance travelled by sound in 0.I s = 344 m/s x 0.1 s = 34.4 m
- So to hear an echo clearly, the minimum distance of the reflecting surface should be half this distance, that is 17.2 m.
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## Reverberation

- Echoes may be heard more than once due to repeated or multiple reflections of sound from several reflecting surfaces. This causes persistence of sound called reverberation.
- In big halls or auditoriums to reduce reverberation, the roofs and walls are covered by sound absorbing materials like compressed fibre boards, rough plaster or draperies.

# Reflection of Sound from Impedance Irregularities

- Mismatches in impedance give rise to reflections, which cause numerous undesirable effects, but can sometimes be desirable effects instead.
- Example: when a sound wave (noise) traveling in an air conditioning duct suddenly encounters the large open space of the room, the impedance mismatch reflects a significant portion of the sound back toward the source. This is considered a desirable effect due to the fact that the air conditioning noise is reduced.